Freezing vegetables

Field of the invention

5   The invention relates to a process for freezing vegetables
       and the frozen vegetables provided thereby. More
       particularly the invention relates to a freezing process
       which provides frozen vegetables of excellent quality when
       defrosted for consumption.

10

Background to the invention

       Various attempts have been in the art to improve the quality
       of vegetables which have been stored frozen by way of the
15   freezing process applied.

       US patent 3,736,154 describes a process of ultraslow
       freezing which discloses the maintenance of intact cell
       membranes in the product by way of a freezing regime with a
20   cooling rate of about 0.1 to 0.3°C per hour. This process is
       disclosed as achieving dehydration of the inner cell as
       water within the cell moves outside the cell membrane where
       it freezes without the destruction of the cell membrane.

25   Unfortunately this process if not a viable approach to the
       commercial preparation of frozen vegetables. Not only does
       this process not tolerate a blanching step which is
       necessary as a microbiological and enzyme deactivation step
       in modern vegetable processing, but also this process takes
30   several days to complete.

US 6 096 361 discloses a similar method of preservation wherein food is relatively rapidly cooled from room temperature to close to the freezing point and then slowly cooled at a gradual cooling rate of 0.01 to 0.5°C/hour to

5   below the freezing point. This non-frozen preservation method may be then followed by a rapid freezing treatment to achieve a food wherein the outer cells of the food are frozen and the inner cell preserved in a non-frozen state. It is disclosed that free water moves from the intracellular

10   fluid to the extra cellular fluid, resulting in the simultaneous dilution of the extra cellular fluid and concentration of the intracellular fluid, which makes it easier for the extra cellular fluid to freeze and, conversely, more difficult for the intracellular fluid to

15   freeze.

An alternative freezing process of the prior art for improving frozen vegetable quality is described in European Patent 0 554 468 B1 in which potatoes are cooked and frozen.

20   Freezing is described as a 2 step process wherein, in a initial step, the core of the potatoes is kept at the crystallisation stage of water for a period of 15 to 60 minutes. In a second step deep-freezing is continued until a storage temperature of -20°C.

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Our European Patent Application No. 02251681 discloses a process for the production of a frozen vegetable or part thereof, wherein said process comprises the steps:
(i) heat treating a vegetable or part thereof;

30   (ii) under-cooling to a maximum core temperature of less than or equal to -5°C;

(iii)   reducing the core temperature to less than or equal to -18°C;

The process produces a frozen vegetable or part thereof comprising a core ice content, in which at least 40% of said core ice content is located within a plurality of cellular structures, wherein the perimeter of each cellular structure is defined by a cell wall. The freezing process can practically eliminate ice formation outside the cell wall of the vegetable tissue and so provide a texture, appearance and thus product quality that was not previously possible in frozen vegetables.

Under-cooling refers to the reduction of the temperature of the vegetable or part thereof to a temperature below the freezing point (i.e. the temperature at which freezing is possible) without the formation of ice crystals occurring.

The core refers to that part of the vegetable or part thereof which is at least 5mm from the external air contact surface. Preferably the core refers to that part of the vegetable or part thereof which is at least 10mm from the external air contact surface, most preferably at least 15mm therefrom.

Extra-cellular ice is an expression used to define ice formed outside the confines of cellular structures, wherein the perimeter of each cellular structure is defined by a cell wall. It therefore follows that intra-cellular ice refers to ice formed within the confines of said cellular structures i.e. within the confines of a cell wall.

Core ice content and the proportion thereof that is intra-
cellular or extra-cellular in its formation is determined by
the following method using low temperature scanning electron
microscopy.

5

Vegetable samples sealed in polythene bags and having been
stored at -80 °C and kept cold during analysis by
transferring them to the Scanning electron microscopy
laboratory in an insulated box containing carbon dioxide.
10 5mm x 5mm x 10mm sub-samples were cut from the chosen
vegetable using a liquid nitrogen pre-cooled scalpel blade
wherein cutting was carried out on an aluminium plate
sitting on a bed of solid carbon dioxide to maintain sample
temperature.

15

These sub-samples were mounted on to a 7mm conical
depression in a 10mm diameter aluminium scanning electron
microscope stub using Tissue-Tek compound (available from
Sakura and comprising <11% polvinyl alcohol, <5% carbowax
20 and at least 85% non-reactive ingredients) at the point of
freezing and immediately plunged in to nitrogen slush. The
stub and sub-sample was mounted on a holder and transferred
to an Oxford Instruments CP2000 low temperature preparation
chamber pumped with an Edwards 306 vacuum station (5 x 10 $^{-7}$
25 Torr) via an airlock. The sample allowed to warm to -95
°C and then fractured using the point of a scalpel blade.
After etching the ice for 5 minutes the sample was cooled to
- 110 °C and coated with Gold/ Palladium (6mA, 6 x 10-1 mBar
Argon, 20 seconds). The vacuum was allowed to recover to 5 x
30 10^{-7} Torr and the sample transferred to a Cressington
Instruments cold stage in a JEOL 6301F Low Temperature Field

Emission Scanning Electron Microscope using an airlock transfer device.

Samples were examined at -150 °C and ice was identified as etched depressions in the fracture surface topography. Images of the intra and extracellular ice were recorded digitally at x 100 and these images then quantified using a Zeiss (Imaging Associates) KS 400 Image Analysis system. Intracellular and extracellular ice content for the core refers to a % of the total ice observed in an image as being located within and outside the cell walls respectively.

The heat treatment step disclosed in European Patent Application No. 02251681 is said to be sufficient to destroy the cell membranes within the vegetable material and by so doing provides a uniform solute concentration across the tissues as free diffusion equilibrates solute levels. This is a necessary precursor to subsequent cooling steps in the process as any variation in solute concentration will give rise to relative variation in the temperature at which freezing will occur and thereby reduce the ability to achieve effective under-cooling.

It is stated the heat treatment of vegetables can also perform a number of other functions by providing pasteurisation of the vegetable material and deactivation of enzymes that accelerate vegetable spoilage such as lipoxygenases.

Preferably heat treatment is undertaken by blanching as this results in the destruction of cell membranes and the

inactivation of some or all of the endogenous enzymes present.

It has now been found that if the heat treatment step is
5   replaced by the firming treatment there is a significant improvement in the cooked texture of the vegetables compared to vegetables subjected to conventional commercial freezing methods.

10 Summary of the Invention

Accordingly, there is provided a process for the production of a frozen vegetable or part thereof, wherein said process comprises the steps:

15

(i)   subjecting a vegetable or part thereof to a firming
       treatment selected from:
                a) immersing the vegetable or part thereof in a
                solution of a calcium salt.
20   b) heating the vegetable or part thereof to a
                temperature in the range 50 to 70°C, and
                c) a combination of a) and b);

(ii) under-cooling to a core temperature of less than or
25   equal to -5°C;
(iii) reducing the temperature to less than or equal to
       -18°C.

30 The process of the present invention provides high quality frozen vegetables to the consumer, and more particularly provides frozen vegetables which, when thawed, give rise to

a product texture and appearance which closely resembles that of fresh vegetables.

The addition of calcium to vegetables is known to limit the
5   softening that vegetables undergo on subsequent higher temperature heating, such as canning or cooking. However, the quality benefits of the calcium addition prior to conventional freezing is somewhat limited. Surprisingly the combination of calcium addition and the controlled freezing
10 regime according to the invention provides a significant improvement.

Pectin is a key component of the cell walls of vegetables and fruits and exists in the form of a gel network. The
15 pectin in the middle lamellae between the primary cell walls of adjacent cells essentially acts as an adhesive between the cells, whilst the pectin matrix within the primary cell wall itself is believed to control the porosity. Enzymes present within the tissue can act on the pectin causing it
20 to change its structure and properties. For example, pectin methyl esterase can de-esterify pectin. The presence or addition of calcium can then lead to cross-links being formed between pectin molecules, which can strengthen the pectin network. This change in the structure and properties
25 of the pectin gel can produce different tissue properties, for example it reduces the softening of the tissue on heating, by limiting the loss in cell adhesion.

Suitable calcium salts include calcium sulphate, calcium
30 chloride, calcium citrate, monocalcium phosphate and mixtures thereof. The salts are employed in aqueous solution generally at a concentration of from 0.1 to 10%

calcium e.g. 1% calcium.   The vegetables or vegetable portions are immersed in the solution, generally for a period of from 2 to 30 minutes e.g. about 15 minutes.

5   Low temperature firming treatment comprising heating to a temperature in the range 50 to 70°C is known to increase the firmness retention in vegetables on subsequent high temperature treatments such as cooking.   It is known that pectin methyl esterase activity is increased by such a

10   heating stage and mediation of firming due to pectin demethylation appears to explain part of the observed increased firmness retention.   The quality benefits of low temperature firming and conventional freezing are limited. However, the combination of low temperature firming and the

15   controlled freezing regime according to the invention provides a significant improvement.   The vegetables are heated to a temperature in the range 50 to 70°C for a period of from 5 to 30 minutes, generally about 15 minutes.

20   The vegetables may be subjected to both the calcium and low temperature firming treatments in either order and simultaneously e.g. by immersing in calcium solution at ambient followed by immersing in calcium solution at 65°C and optionally immersing again in calcium solution at

25   ambient temperature.

The controlled freezing regime comprises undercooling to a maximum core temperature of less than or equal to -5°C and reducing the core temperature to less than or equal to -

30   18°C.

Under-cooling 'the core' of the vegetable or part thereof to
a maximum temperature of less than or equal to -5°C ensures
that enough heat has been removed from the material to allow
rapid and uniform ice formation in the freezing step (iii)

5   and thereby provide a significant reduction in extracellular
ice formation. Preferably the vegetable or part thereof is
under-cooled to a temperature from -5 to -15°C, most
preferably from -7 to -12°C. It has been shown that merely
reducing the core to -1 or -2°C without further under-

10 cooling is not sufficient for the rapid initiation of
freezing needed for the desired reduction in extracellular
ice and consequent product benefit.

In order to under-cool effectively, without initiating ice
15 crystal formation, the temperature difference between the
centre of the core and the surface of the vegetable or part
thereof must be kept to a minimum.

It has been shown that temperature differences between core
20 and surface at the point of initiation of ice formation can
vary significantly with conventional approaches to freezing.
With the conventional blast freezing, when the surface of
the vegetable material reaches 0°C and ice formation starts,
the core is much warmer and the initiation of ice formation
25 in this region starts much later.

Conventional wisdom accepts that the quicker the temperature
drops during freezing, the more rapidly freezing occurs and
the more favourable the vegetable properties achieved.
30 Commercial preparation of frozen vegetables has therefore
sought to speed up the cooling rates of commercial freezing
equipment. It is counter intuitive and therefore surprising

to now find that where the rate of cooling is slowed to achieve a defined level of under-cooling within the vegetable core initiation of freezing can be induced throughout a product almost instantaneously.

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In accordance with the present invention there is provided a process therein the rate of cooling is slowed sufficiently to achieve only a small temperature difference between core and surface and thereby induce under-cooling at the core of

10 the vegetable material to a maximum temperature of less than or equal to -5°C. Ice formation with further temperature reduction can then occur throughout the vegetable material at approximately the same time. This has been found to result in a higher proportion of ice crystal formation

15 within the cell structures defined by the cell walls i.e. intracellular ice and more favourable vegetable properties when consumed.

The temperature difference between the core and surface, and

20 also within the core itself is dependent on the rate of cooling of the vegetable material. Rate of cooling is in turn dependant on the size of the vegetable material to be frozen and the surface area that it exhibits. It is believed to be within the capability of the person skilled

25 in the art to decide on an appropriate cooling rate to achieve under-cooling to maximum core temperature of less than or equal to -5°C for a vegetable of a particular size and surface area.

30 Sensory analysis has confirmed that both the appearance and the texture of vegetables prepared according to the present invention show improvement over the conventional freezing

methods known in the art and the results obtained closely resemble those for fresh unfrozen vegetables. In particular the firmness of vegetables according to the invention are significantly improved over frozen vegetables known in the

5   art.

To ensure effective under-cooling it is preferred that the cooling rate utilised for the process of the invention maintains maximum and minimum temperatures between the

10   surface and the core within 6°C of each other, preferably less than or equal to 3°C, most preferably less than 1.5°C of each other e.g. two temperature probes are inserted into the vegetable e.g. a potato which is being cooled according to the invention, the first at 10mm from the surface of a

15   potato tuber and the second in the centre of the tuber; when the first probe detects a temperature of 0°C the second should read less than or equal to +6°C, preferably less than or equal to +3°C, most preferably less than +1.5°C.

20   Preferably the vegetable material will be cooled in a blast freezer wherein the freezer set-point is progressively reduced according to the following regime:

       55-65 minutes at 0°C

25   25-35 minutes at -5°C

         10-20 minutes at -10°C

         10-20 minutes at -12.5°C

         70+ minutes at -30°C

     Most preferably the vegetable material will be frozen in a

30   blast freezer wherein the freezer set-point is reduced according to the following regime:

60-70 minutes at -12°C   downwards airflow about 1 m/s

25-35 minutes at -30°C   downwards airflow about 4.5 m/s

5   The temperature at which initiation of freezing occurs in
step (iii)will depend on the nature of the vegetable that is
being subjected to this freezing process, the rate at which
cooling continues below -5°C as well as the presence or
absence of nucleating agents.   Initiation of freezing may
10 occur at any point when the temperature within the core is
at a maximum of less than -5°C.   Typically initiation of
freezing will occur when the temperature within the core is
at a maximum temperature of from -7°C to -12°C.

15 In one embodiment of the process at least 40% of ice
formation within the core of said vegetable or part thereof
in step (iii) occurs within a plurality of cellular
structures, wherein the perimeter of each cellular structure
is defined by a cell wall. Preferably at least 60 % of said
20 ice formation occurs within said plurality of cellular
structures, more preferably 80%. Most preferably 90% of ice
formation at the core of said vegetable or part thereof
occurs within said plurality of cellular structures.

25 In a vegetable prepared according to the present invention
it is preferred that at least 60% of said ice formation
occurs within said plurality of cellular structures, more
preferably 80%. In a most preferred embodiment 90% of ice
formation at the core of said vegetable or part thereof
30 occurs within said plurality of cellular structures as these

vegetables most closely resemble the appearance and texture of fresh vegetables.

The effect of extra-cellular ice formation on the cellular
5   structure of the vegetable material has been demonstrated, wherein the cavitation in thawed vegetables caused by extra-cellular ice growth has been quantitatively evaluated.

Measurements have been carried out to demonstrate the
10   differences in the disruption of the cellular structures in thawed vegetables between conventional freezing and freezing by a process of the invention.

Fixation Method: The tissue pieces were received already
15   thawed.   They were transferred to fixative, formol-acetic alcohol (FAA) at room temperature and left to fix for not less than 72 hours.

Embedding & Sectioning: After fixation, the tissue pieces
20   were dehydrated and embedded in paraffin wax.   They were then sectioned to a nominal thickness of 5μm, and mounted on glass slides.

Sections were cut through the tissue pieces which had been
25   subjected to the different freezing treatments.   Three images were selected from each section, two from opposite sides of the tissue section (avoiding tissue very close to the edge of the section) and one image from near the middle. Care was taken to ensure that there was no overlap between
30   the fields.
For image enhancement the images were first converted to B/W (18-Bit) format and image contrast was greatly increased by

carrying out a 100 pixel value downfield shift of the entire image, followed by re-ranging it back to its full dynamic range (pixel value range 0 - 255). This left the cell walls a very dark grey and remainder of the image a very light

5   grey.

The ice cavities were identified by eye from their morphology. Using the 'magic wand' range selector, set to a tolerance of ±15, with the contiguity control switched on,

10 the cavities were selected manually and filled with white (pixel value = 255). The remainder of the image was rendered black (pixel value = 0).

Measurements were done on a Kontron KS300 image analyser.

15 The total number of pixels in the ice cavities were counted (measured as a filled area - i.e. treating any small inclusions within the cavities as if they were not there), added together and expressed as a percentage of the pixels in the entire image.

20

For the purpose of the present invention a vegetable or part thereof may be selected from the group comprising potato, swede, turnip, pumpkin, onion, broccoli, tomato, zucchini, aubergine, water chestnut, pepper, mushroom, peas, carrot,

25 spinach, sugar-snap peas, green bean and mange-tout. Most preferably said vegetable or part thereof is tomato.

Vegetable or parts thereof according to the present invention can be readily used in a variety of commercial

30 catering or domestic frozen food products. In particular vegetables of the present invention are ideally suited to frozen ready prepared meals where their superior texture

considerably improves the product quality. Therefore a further aspect of the invention relates to the use of a vegetable of part thereof as described above in a frozen meal.

5

Description of the Drawings

Figures 1 to 3 represent plots of force (N) against displacement (mm) obtained from compressive mechanical tests

10   conducted on samples from Examples 1 to 3 respectively, and

Figures 4 to 7 represent low temperature scanning electron microscope images conducted on samples from Example 3.

15   Figures 8 and 9 represent plots of force (N) against displacement (mm) obtained from compressive mechanical tests conducted on samples from Examples 4 and 5 respectively.

The invention will be illustrated by the following Examples
20   in which the following techniques were employed:

Vegetable Freezing Method (Controlled Cooling)

The freezing method used a Montford Environment Test Chamber. This programmable piece of apparatus is capable of
25   producing very finely controlled temperature gradients in a reproducible manner. The programme used gives rise to a linear gradient down from +10° to -30°C over 16 hours. The vegetables were transferred to the chamber and then frozen using the 16 hour gradient programme.

30

Compressive Mechanical Tests of Tomatoes

The mechanical plots show typical compressive mechanical tests on pieces of tomato cut from the outer pericarp of several fruits. The pieces were either frozen raw or initially heated and/or immersed in calcium solution as
5   described by the invention, prior to being frozen by the process of the invention or by conventional blast freezing. After freezing, the pieces were thawed by immersion in ambient water. For each regime, ten pieces were tested and a typical force-displacement plot was chosen to represent
10 each regime.

For the purposes of the mechanical tests, 1cm diameter cylinders of tissue were cut from the pericarp of the tomato using a corkborer. These pieces were processed as described
15 previously. The tissue cylinder was then compressed with a flat plate to about 70-80% strain at a crosshead speed of 2400mm/min using a Dartec Series HC10 Servo-Hydraulic Testing System.

20 Tomato Cooking
Cooking was conducted on tomato portions (whole tomatoes cut into 4 to 6 portions while still frozen). The portions were cooked by frying in oil until they reached a temperature of at least 70°C.
25

Example 1
The following tests were conducted:

a)   Calcium firming and controlled cooling (Ca/CC)
30 Tomato pieces were immersed in 1% calcium chloride solution for 15 mins followed by freezing by Controlled Cooling(CC). Tomato pieces were then cooked from frozen.   Intact pieces

apparent with skin still attached, minimal fluid released and a firm texture in-mouth and to fork.

b)   No firming treatment and controlled cooling (Raw/CC)

Raw tomato pieces were frozen by controlled cooling. Tomato
5   pieces were cooked from frozen.   The cooked tomato pieces were very soft, wet, lots of fluid lost and skin coming away from flesh.

c)   No   firming   treatment   and   conventionally   frozen
10   (Raw/blast)

Raw tomato pieces were frozen in a conventional blast freezer set to -30°C throughout the freezing process.

Tomato pieces were cooked from frozen.   The cooked tomato
15   pieces were similar to those of test b) (Raw/CC).

d)   Calcium firming and conventionally frozen (Ca/blast)

Raw tomato pieces were immersed in 1% calcium chloride solution for 15 minutes followed by freezing in a
20   conventional blast freezer set to -30°C throughout the freezing process.

Tomato pieces were cooked from frozen.   The cooked tomato pieces were less intact than those from test a) and
25   disintegrated with a fork.

Compressive Mechanical Tests

Compressive mechanical tests were conducted on thawed samples from tests a) (Ca/CC), b) (Raw/CC) and d)
30   (Ca/blast). The results are reported in Figure 1.

It will be seem from Figure 1 that the strength (max force prior to failure) is greater for the thawed samples treated

according to the invention (Ca/CC) than samples treated by Raw/CC or Ca/blast. The initial gradient (stiffness) and area under curve prior to failure (energy to failure) are also greater. These mechanical parameters are known to

5   relate to the perceived in-mouth texture (firmness) of the tissue.

Example 2

The following tests were conducted:

10

a)   Heating at 65°C and controlled cooling (65C/CC)

Tomato pieces were immersed in water at 65°C for 15 minutes followed by freezing by controlled cooling. Tomato pieces were cooked from frozen.

15

b)   No firming treatment and controlled cooling (Raw/CC)

Test b) as in Example 1.

c)   No firming treatment and conventionally frozen

20   (Raw/blast)

Test c) as in Example 1.

d)   Heating at 65°C and conventionally frozen (65C/blast)

Tomato pieces were immersed in water at 65°C for 15 minutes

25   followed by freezing in a conventional blast freezer set to -30°C throughout the freezing process.

30

Tomato pieces were cooked from frozen. The results of the tests a) to d) are summarised in the following Table.

5

TEST	RESULT AFTER COOKING
c) Raw/blast	V. mushy/difficult to cut; Pericarp to paste
d) 65C/blast	Less mushy, but soft, watery
b) Raw/CC	Firmer, more structure in tomato; easier to cut
a) 65C/CC	Firmer to cut

Compressive Mechanical Tests

Compressive mechanical tests were conducted on thawed
10 samples from tests a), b) and c). The results are reported in Figure 2.

It will be observed from Figure 2 that the strength of the samples treated in accordance with the invention (65C/CC) is
15 superior to the other samples.

Example 3

The following tests were conducted:
20

a)   Calcium and low temperature firming and controlled cooling (Ca 65C/CC)

Tomato pieces were immersed in 1% calcium chloride solution
25 at ambient temperature for 5 minutes, followed by immersion in 1% calcium chloride solution at 65°C for 5 minutes

followed by immersion in 1% calcium chloride solution at ambient temperature for 5 minutes.

Thereafter the tomato pieces were frozen by controlled cooling.

5

Tests b), and c) were repeated as in Example 2. Test d) was the same as Test a) above, except that blast freezing was used instead of controlled cooling.

10 Compressive Mechanical Tests

Compressive mechanical tests were conducted on thawed samples from test a) and compared to thawed samples from b) untreated/ controlled cooled (Raw/CC), c) untreated/conventionally frozen (Raw/blast) and d) calcium

15 firming/conventionally frozen (Ca/blast). The results are reported in Figure 3.

It will be observed from Figure 3 that the strength of the samples treated in accordance with the invention (Ca65C/CC)

20 is superior to the other samples. The initial gradient (stiffness) and area under the curve prior to failure (energy to failure) are also greater.

Preparation of frozen tomato for quantitative evaluation of

25 intra-cellular and extra-cellular ice content using low temperature scanning electron microscopy (LTSEM)

Frozen tomato samples in sealed polythene bags that had been stored at -80 °C were kept cold by transferring them to the

30 Scanning electron microscopy laboratory in an insulated box containing carbon dioxide.

Approximately 5mm x 5mm x 10mm sub-samples were cut 10mm from the outer edge of each sample using a liquid nitrogen pre-cooled scalpel blade. Cutting was carried out on an Aluminium plate sitting on a bed of solid carbon dioxide to

5 maintain sample temperature. Sub-samples were mounted on to a 7mm conical depression in a 10mm diameter Aluminium scanning electron microscope stub using TissueTek compound at the point of freezing and immediately plunged in to Nitrogen slush. The stub + sample was mounted on to a holder

10 and transferred to an Oxford Instruments CP2000 low temperature preparation chamber pumped with an Edwards 306 vacuum station (5×10^{-7} Torr) via an airlock. The sample was allowed to warm to -95 °C and fractured using the point of a scalpel blade. After etching the ice for 5 minutes the

15 sample was cooled to - 110 °C and coated with Gold/ Palladium (6mA, 6 x 10-1 mBar Argon, 20 seconds). The vacuum was allowed to recover to 5×10^{-7} Torr and the sample transferred to a Cressington Instruments cold stage in a JEOL 6301F Low Temperature Field Emission Scanning Electron

20 Microscope using an airlock transfer device.

Samples were examined at -150 °C and ice was identified as etched depressions in the fracture surface topography. Representative images of the intra and extracellular ice

25 were recorded digitally at x 100 and these images then quantified using a Zeiss (Imaging Associates) KS 400 Image Analysis system.

Figures 4 to 7 are LTSEM images for tomato samples subjected

30 to Ca65C/CC, Raw/CC, Raw/blast and Raw/blast respectively.

Figure 4 shows ice crystals within the cells and intact tissue structure. The tissue is firm when thawed.

Figure 5 shows large ice crystals, some in cells with some
5   cells intact and damaged tissue.
Figure 6 shows large ice crystals with very damaged tissue structure. The tissue is soft and watery when thawed.

Figure 7 also shows large ice crystals and very damaged
10 tissue.

Example 4

Whole new harvest potatoes (var Charlotte) were treated and
15 analysed as follows:

Whole tubers (30 to 40g size range) were subjected to a firming treatment by immersion in water heated to 65°C for 10 minutes and then allowed to air cool for 10 minutes at
20 room temperature. The potatoes were then blanched by immersion for 12 minutes in boiling water. Other potatoes from the same batch that had not been subjected to firming at 65°C were also blanched in boiling water for 12 minutes.

25 Firmed and non firmed potatoes were then frozen either conventionally in blast freezer or by controlled cooling. After freezing the tubers were thawed by immersion in water at ambient temperature. Samples from each processing regime were cut from the parenchyma region of different tubers,
30 pieces were cut to 1cm cubes using a scalpel blade. The pieces were compressed with a flat plate to 70 to 80% strain at a cross head speed of 2400mm/min using a Dartec Series

HC10 Servo-Hydraulic Testing System. For each process six
pieces from different tubers were tested. A typical force
against displacement plot is shown in Figure 8.

5   It can be seen from Figure 8 that the stiffness (initial
gradient), strength (maximum force required prior to
failure) and area under the curve prior to failure are all
greater for the potato pieces that have been subjected to a
firming treatment and then frozen by the controlled cooling

10   process. These mechanical parameters are accepted to relate
to the textural perception of food stuffs in-mouth and
clearly show a greater retention of the typical attributes
of high quality vegetables.

15   Example 5

Frozen whole potatoes produced by each of the four regimes
described in Example 4 were added to a pan of boiling water
for 17 minutes until judged to be fully cooked. Each of the

20   samples was then served in a randomised order for tasting
and assessed against a series of appearance and textural
attributes.

The potatoes that had been frozen by controlled cooling were

25   more intact, showed no skin splitting and were firmer to the
cut and taste than the tubers that had been conventionally
frozen with or without a firming treatment. However, the
potatoes that had been subjected to a firming treatment
prior to being frozen by the controlled cooling process

30   showed an even greater improvement in texture with a firm,
waxy texture very close to that of a fresh, non-frozen high
quality potato.

Example 6

Carrot roots were cut into pieces of approximately 50g and
treated as follows:

5

Carrot pieces were subjected to a firming treatment by
immersion for 20 minutes in water heated to 65°C and then
allowed to air cool for 10 minutes at room temperature. The
carrot pieces were then blanched by immersion for 8 minutes
10   in boiling water. Other carrot pieces from the same batch
that had not been subjected to firming at 65°C were also
blanched in boiling water for 8 minutes.

Firmed and non firmed carrots were then frozen, either
15   conventionally in blast freezer, or by controlled cooling.
After freeing the pieces were thawed by immersion in water
at ambient temperature. Samples from each processing regime
were cut to 1cm cubes from the pith region of different root
pieces using a scalpel blade. The pieces were compressed
20   with a flat plate to 70 to 80% strain at a cross head speed
of 2400mm/min using a Dartec Series HC10 Servo-Hydraulic
Testing System. For each process six pieces from different
roots were tested. A typical force against displacement
plot is shown in Figure 9.

25

It can be seen from Figure 9 that the strength (maximum
force required prior to failure) and the area under the
curve prior to failure are all greater for the carrot pieces
that have been subjected to a firming treatment and then
30   frozen by controlled cooling. These mechanical parameters
are accepted to relate to the textural perception of food

stuffs in-mouth and clearly show a greater retention of the typical attributes of high quality vegetables.

Example 7

5

Sensory assessment of frozen tomato pieces.

This Example compares the sensory assessment of meals prepared from frozen tomato pieces which were frozen by
10   conventional blast freezing or controlled cooling with and without a heat firming treatment.

Frozen salad tomato pieces were added to a frozen meal which was stir fried for 13 min.

15

Meal appearance was evaluated by a panel of 16 trained sensory assessors. The meal was presented on white china plates. Each sample contained 8 pieces of tomato amongst rice. Total meal weight was 200g.

20

The following attributes were evaluated as follows:

Impression of whole pieces

25   The amount of large, whole pieces of tomato that appear to be present across the whole sample on the plate.

Structural strength

30   Whether the tomato pieces appear to be self-supporting or collapse.

Intactness of pieces

The degree to which the individual tomato pieces in the sample are intact or broken down.

5

The following contains the adjusted mean scores for each of the four samples in terms of tomato appearance. (Values followed by the same letter were **not** significantly different (p = 0.05)).

10

Attribute	Raw blast	Heat Treat blast	Raw CC	Heat Treat CC
Impression whole pieces	2.99a	3.22ab	3.72b	4.46c
Structural strength	2.51ab	2.14a	2.92b	3.5c
Intactness of pieces	2.49a	2.68ab	3.08bc	3.5c

The data shows that the heat treated controlled cooled sample gave the impression of having significantly more whole tomato pieces with more structural strength than any
15 of the other samples.

The tomato pieces in the heat treated controlled cooled sample were also judged to be significantly more intact than either of the blast frozen samples. The tomato pieces in
20 the heat treated controlled cooled sample were also ranked more intact than no heat treated controlled cooled sample but the difference was not significant (p = 0.05).